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Stoves or Sugar? Willingness to Adopt Improved Cookstoves in Malawi

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Abstract

Malawi has set a target of adoption of two million improved cookstoves (ICS) by 2020. Meeting this objective requires knowledge about determinants of adoption, particularly in rural areas where the cost of traditional cooking technologies and fuels are non-monetary, and where people have limited capacity to purchase an ICS. We conducted a discrete choice experiment with 383 households in rural Malawi asking them if they would chose a locally made ICS or a package of sugar and salt of roughly equal value. Six months later, we assessed adoption and stove use patterns. Sixty-six percent of households chose the ICS. We find that having a larger share of crop residues in household fuel supply, awareness of the environmental impacts of woodfuel reliance, time the primary cook devotes to collecting fuelwood, and peer effects at the village-level increase the odds of choosing the ICS. Having a large labor supply for fuelwood collection and experience with a non-traditional cooking technology decreased the odds of choosing the ICS. In a rapid assessment six months after stoves were distributed, we found 80% of households were still using the ICS, but not exclusively. Our findings suggest considerable potential for wide-scale adoption of ICS in Malawi.

Keywords

adoption; biomass; cookstoves; fuelwood; Malawi; Sub-Saharan Africa

1. Introduction

Approximately 3 billion people or 40% of the global population rely on solid fuels including fuelwood, charcoal, crop residues, and dung for cooking and heating (Pachauri et al., 2012). While several countries have made considerable gains with respect to access to modern fuels and improved cooking technologies (e.g., Brazil and China), transitions to modern energy

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systems remain elusive throughout much of the developing world. Nowhere is this more pronounced than in sub-Saharan Africa, where the absolute number of people reliant on woodfuels (fuelwood and charcoal) to meet basic household energy needs will increase in coming decades (Riahi et al. 2012). Heavy reliance on woodfuels has implications for human and terrestrial systems. Fuelwood is the most important subsistence forest product (in value terms) that rural households in sub-Saharan Africa harvest (Angelsen et al., 2014; Dewees et al., 2010; Fisher, 2004; Jagger, 2012). While the region is urbanizing, this does not necessarily reduce woodfuel dependence; city dwellers rely heavily on charcoal for their daily cooking needs (Bailis et al., 2015). In sub-Saharan Africa woodfuels account for 75% of total wood harvest, contributing to deforestation (in hotspot areas, for example Ethiopia) and more commonly forest degradation (Ibid). Obtaining energy from wood is a massive mobilization of resources, carried out by millions of people every day, resulting in large burdens on both people and environment (Masera et al., 2015).

Despite persistent efforts by the energy and natural resource management communities, transformations in the domestic household energy sector have proven elusive over the past several decades (Arnold et al., 2006). Policy frameworks for reducing woodfuel consumption include regulations governing fuelwood harvesting and charcoal production (Schure et al. 2015), introduction of modern fuels (e.g., electricity and liquid petroleum gas), and promotion of energy saving cooking technologies (Schure et al. 2014). Our study focuses on adoption and sustained use of improved cookstoves (ICS) as a policy that is being widely promoted in the region to reduce environmental impacts and improve the well-being of rural people, but which to date has had limited traction in rural African settings.

Two streams of new knowledge have rekindled the interest of the international development community and brought new attention to addressing household energy issues. First, there is a growing body of evidence on the role of household air pollution (HAP) from solid fuels and traditional cooking technologies as a risk factor for a variety of health outcomes including acute respiratory infection (ARI) among children under five years old, chronic obstructive pulmonary disease (COPD) and chronic obstructive lung disease for women, low birth weight and a host of other acute and chronic illnesses (Ezzati, 2005; Ezzati et al., 2002; Smith, 2000; Smith-Sivertsen et al., 2009). The 2010 Global Burden of Disease Study reports that household air pollution (HAP) and ambient particulate matter (PM) accounted for 3.5 million and 3.1 million deaths respectively, and 4.5 and 3.1% of global disability adjusted life years (DALYs). While HAP decreased from 2nd to 4th in the global ranking of DALY risk factors between 1990 and 2010, it remains the second most important risk factor globally for women (who do most of the cooking in developing countries), and the 2nd most important risk factor, after childhood underweight, in sub-Saharan Africa (Lim et al., 2012).

Second, the role of incomplete combustion from burning solid fuels and reliance on traditional cooking technologies in regional climate change has been documented (Hicks and Demkine, 2011; Ramanathan and Carmichael, 2008). Black carbon or ‘soot’ from burning biomass fuels has been identified as the second largest contributor to anthropogenic climate change after carbon dioxide emissions. Net emissions from unsustainable harvesting of woodfuels are estimated to contribute 2–8% of global anthropogenic climate forcing, and 20% of black carbon emissions globally (Masera et al., 2015). Moderating chronic disease and mitigating climate change are viewed as a ‘double-dividend’ public investment; actions relating to energy use and behavior choices could have large and immediate impacts on both local health and greenhouse gas emissions (Kandlikar et al., 2009; Smith and Balakrishnan, 2009; Smith et al., 2010).

This paper focuses on willingness to adopt improved cookstoves (ICS) in Malawi where household air pollution from traditional cooking is the most important risk factor for burden of disease (IHME, 2013), and regional climate change is a pressing issue (Ahmed et al., 2009; Fullerton et al., 2009; Martin et al., 2014). Malawi is also an important case as it has relatively high rates of deforestation, suggesting that some parts of the country will experience fuel scarcity in the coming years (Bandyopadhyay et al., 2011; Hansen et al., 2013; Kamanga et al., 2009). Woodfuels primarily sourced from natural forests account for more than 90% of energy consumption (Jumbe and Angelsen, 2011). Only five percent of the population has access to electricity which is delivered at relatively high cost and with unreliable service (MARGE, 2009). Biomass burning from domestic cooking, small-scale industry, agricultural processing, and clearing of forests for agriculture contributes to regional climate change; the Government of Malawi estimates that forest-based emissions account for nearly 80% of the nation’s overall carbon-footprint (GoM, 2015).

In January 2013, the Government of Malawi announced a target of distributing two million clean and efficient cookstoves throughout the country by 2020. This is a particularly ambitious policy objective given that over 90% of households currently burn solid fuels using traditional three-stone stoves. By 2020 there will be an estimated four million households in Malawi. If successful, half of all households in Malawi will have adopted improved cookstoves. As part of a study on linkages between forests, energy and livelihoods we conducted an experiment on ICS adoption in two field sites in rural Malawi. To understand underlying preferences for improved cooking technologies, we carried out a discrete choice experiment in which survey respondents were asked to choose between a low cost locally produced ICS (locally referred to as ‘chitetezo mbaula’ meaning ‘protecting stove’), and a package of dry goods including sugar and salt, common kitchen staples, of equal cash value to the ICS. After all surveys were completed in a village, respondents were given their choice, along with a brief tutorial for those who chose stoves. We quantitatively test a comprehensive set of hypotheses related to cookstove adoption. Six months after the ICS were distributed we conducted a rapid assessment to evaluate levels of adoption and the extent of utilization. Our approach is to comprehensively test several factors hypothesized to motivate cookstove adoption.

In anticipation of high levels of public investment in interventions aimed at providing incentives for households to transition to cleaner fuels and technologies, there is a need to strengthen the relatively weak theoretical and empirical evidence base on determinants of adoption. Several recent meta-analyses have reviewed the literature on improved cookstove adoption including Lewis and Pattanayak (2012), Puzzolo et al., (2013), and Rehfuess et al., (2013). Much of the research on ICS adoption is focused on household-level determinants including income, household size and education levels (Chen et al., 2005; Duflo et al., 2008; Gupta and Köhlin, 2006; Heltberg, 2005; Kavi Kumar and Viswanathan, 2007; Khushk et al., 2005). Several factors are known to increase the likelihood of ICS adoption including household income, education (especially for females), household size, and access to credit (Edwards and Langpap, 2005). Female-headed households tend to adopt cleaner fuels and technologies (Lewis and Pattanayak, 2012). Factors such as house ownership and presence of a kitchen also influence households to adopt stoves (Rehfuess et al., 2013). Information or level of awareness is generally associated with adoption: perceptions of reduction in smoke-related health effects, risk of burns and house fires; and increase in cleanliness (i.e. cleaner homes and vessels) have been identified as enablers of stove adoption and utilization (Barnes et al., 2012; El Tayeb Muneer Mohamed, 2003).

Several factors are known to reduce the likelihood of ICS adoption. Prioritization of other basic needs relative to improved stoves, and reliance on free traditional stoves may deter households from purchasing improved stoves (Mobarak et al., 2012). Rural households and marginalized social groups are less likely to adopt ICS (Lewis and Pattanayak, 2012). Other barriers to ICS adoption include capital costs and poor designs that are not complementary to traditional cooking practices (Pandey and Yadama, 1992; Troncoso et al., 2007). For example, Barnes et al. (1994) found that stoves that are similar to a traditional stove, designed according to consumer preference, easy to light, use different wood sizes, and are produced by local artisans using local materials have the highest adoption rates.

The issue of free, subsidized or full cost stoves has gained a lot of attention in light of recent ICS interventions and programs. Stove cost, stove subsidies, flexible pricing schemes, and access to credit are factors that determine stove adoption (Rehfuess et al., 2013). Stove demonstrations and ‘word-of-mouth’ are important for stove demand creation, while strength of production, dissemination and maintenance of stoves determine a business model’s sustenance in the long-run. Miller and Mobarak (2011) found that women preferred improved stoves when offered free of cost, but other evidence (Barnes et al., 1994) suggests that stove usage and maintenance rates are unacceptably low in programs that offer stoves at no cost.

The role of fuelwood supply in ICS adoption is poorly understood (Amacher et al., 2004; Cooke 1998, 2000; Gupta and Köhlin, 2006; Jagger and Shively, 2013; Kohlin, 1998; Van’t Veld et al., 2006). There is inconclusive evidence that time savings in the form of reduction in fuel collection time and cooking time are important considerations for rural households when making stove purchase decisions (Rehfuess et al., 2013). Other meso-level variables considered in case studies examining ICS adoption include own and cross price elasticities for different fuels (Gupta and Kohlin, 2006); presence of community-based institutions focused on sustainable forest management (Jumbe and Angelsen, 2011); community coordination and public provision of services (Macht et al., 2007; Pandey and Yadama, 1992; Pattanayak and Pfaff, 2009; Sinton et al., 2004) population growth rates (Arnold et al., 2006; Baland et al., 2010); altitude; and forest area per person (Turker and Kaygusuz, 2001).

Several debates persist in the public health, environment, and international development communities regarding how to motivate people to switch from traditional to improved stoves. Key questions include whether stoves should be partially or fully subsidized given the individual and collective positive externalities associated with ICS uptake, how much training, technical support, and follow-up is required to ensure adoption and utilization, and how important it is to promote locally designed and manufactured technologies (Jeuland and Pattanayak, 2012; Mobarak et al., 2012).

We offer three contributions to this growing number of quantitative studies that examine factors influencing the adoption of ICS in developing countries. First we test a comprehensive set of hypotheses related to demand, supply, cook and cooking area characteristics, knowledge and perceptions about ICS, and meso-level factors. Few studies systematically and simultaneously test a full set of hypothesized determinants of ICS adoption. Second, we test important aspects of implementation of ICS programs including whether people use stoves provided for free, and the importance of engagement with stove users after stoves are distributed. Finally, the published literature concerning the adoption of cookstoves and modern fuels in sub-Saharan Africa is sparse compared to Asia and Latin America (c.f., Silk et al., 2012; Takama et al., 2011; El Tayeb Muneer Mohamed, 2003). Our study in rural Malawi provides empirical evidence of the potential for wide-scale adoption and utilization of ICS in very low-resource settings in rural Africa.

2. Methods

Between October and November, 2013, we conducted a household-level socioeconomic survey (Malawi Forests and Livelihoods Survey (MFLS)) with approximately 400 households in rural Malawi.[1] The MFLS is a four-wave village and household-level survey with focus on both community-based forest management and the role of environment income as a contributor to rural livelihoods (Chibwana et al., 2012, 2013; Jumbe and Angelsen, 2006). In addition, each wave has unique modules focused on different themes. In the fourth wave, we added modules to the survey about cooking, fuel and stove decisions and preferences, detailed information on kitchen design and ventilation, health status for women and children, and nutrition. At the end of each survey, we asked respondents the following question:

> "If given a choice between receiving an improved cookstove (chitetezo mbaula) and a basket of consumption goods (e.g. sugar, salt) of equivalent value for participating in this study, which option would you choose?"

The question was directed to the primary cook in the household, but respondents were free to consult with other household members on the choice. In cases where households were not familiar with the chitetezo mbaula, enumerators showed the respondent(s) a photograph of the stove and briefly explained how it works (Figure 1). Households were asked to make a decision which was recorded by the enumerator administering the survey. After all surveys were completed in a village, households received whatever they selected – either the stove or sugar/salt. A tutorial was provided to all households that chose stoves along with a fact sheet indicating operating procedures and care and maintenance of the ICS. Six months after the stoves were distributed we conducted a rapid assessment of stove adoption and utilization. This involved visiting roughly half of the households that selected the stove and asking a series of questions about adoption and utilization experiences.

[1]More information about the MFLS can be found at http://fuel.web.unc.edu/mfls-survey/.

We selected the chitetezo mbaula because of its relatively low cost and rising popularity in Malawi. When the Government of Malawi announced the policy objective of scaling-up to two million ICS by 2020, Joyce Banda, then President of the Republic of Malawi, participated in a cooking demonstration using the chitetezo mbaula. The stove is produced by local women's groups, is designed to burn fuelwood and crop residues, is portable, and caters for various pot sizes. Results from a recent study suggest that use of the chitetezo mbaula reduces fuel consumption by approximately 34–43% (Malakini et al. 2014). It is estimated that a household that replaces the three-stone fire with a chitetezo mbaula saves just less than one ton of fuelwood/year (UNFCCC, 2015). Qualitative surveys of stove users undertaken by the international non-governmental organization Concern Universal, who has played a major role fostering local producers groups and markets for improved cookstoves, suggest that the chitetezo mbaula is perceived to produce less smoke in the kitchen, is safer, and reduces both cooking and fuelwood collection times and/or frequencies.[2] The life span of the stove ranges from 1 to 5 years depending on how the stove is cared for. These potential benefits were explained to all respondents at the end of the interview, and prior to making their decision regarding whether to choose the stove or sugar. The chitetezo mbaula retails for the equivalent of $2–3 USD in rural trading centers; the basket of dry goods we assembled (sugar and salt) was of equal value.

2.1 Study area, sampling, and survey instruments

Our data were collected in Kasungu and Machinga Districts. Kasungu District is roughly 300 kilometers north of Lilongwe, the capital city of Malawi (Figure 2). The 26 study villages are adjacent to the Chimaliro Forest Reserve, an important source of legally accessed fuelwood and other subsistence forest products. The forest reserve plays an important role in the livelihoods of local people, and is collaboratively managed by the Malawi Department of Forestry and local community members organized into Block Management Groups (IIED, 2008). Kasungu has a relatively low population density as compared with the Machinga site (Table 1). The average land holding is 1.5 hectares (National Statistical Office, 2010). The main agricultural crops planted are maize and tobacco; a variety of vegetables are grown in wetland areas. Many households keep livestock including cattle and goats. Access to major markets in Malawi is limited, though there is considerable cross border trade with Zambia.

The 18 villages in Machinga District, about 200 kilometers south of Lilongwe, are adjacent to Liwonde Forest Reserve which is a major source of fuelwood (legally harvested) and charcoal (illegally produced) for nearby urban centers Zomba and Blantyre, as well as for the local community. As with the Chimaliro Forest Reserve, local communities collaboratively manage the Liwonde Forest Reserve. The study villages are in a relatively population dense part of the country; the average land holding is 0.76 hectares (National Census of Agriculture and Livestock, 2010). The main agricultural crops planted are maize and paddy rice. There is limited investment in livestock; some households keep chickens and other small animals. The study area has relatively good market access with three of Malawi's 15 largest urban centers within 100 kilometers of the study area (Balaka, Liwonde,

[2]Personal communication, Yamungu Botha, Program Manager, Concern Universal, Malawi.

and Zomba). Deforestation due to fuelwood collection is not a factor in either study site, though fuelwood collection is likely contributing to forest degradation in both sites. In the Machinga site rural households engage in charcoal production for urban markets which contributes to deforestation. In both study areas cooking takes place at the individual household-level (vs. communal activity organized among multiple households as in other parts of Africa). M

Our sample is drawn from the fourth wave of the MFLS a household-level panel of approximately 400 households. The study areas were selected by Jumbe in 2002 as representative of areas with relatively high forest reliance and active forest co-management agreements. The original villages were selected using a stratified random sampling approach that took into account population density, market access, proximity to forest reserves, and whether there was a co-management agreement in place. After villages were selected, households were randomly selected in each village after a census of current households was conducted. With each successive round of the MFLS (2006, 2009, 2013) households were replaced due to attrition, with the aim of maintaining a sample of roughly 400 households. Roughly 50% of the original sample has been retained, meaning that our sample has a bias towards older and more established households. Our analysis leverages only the 2013 data, which were collected in October/November 2013 at the tail end of Malawi's long dry season. Our total sample size is 383 households nested within 44 villages.

For our study we defined a household as a group of people that regularly eat together. The household survey has modules on household demographics, assets, land and livestock ownership, agricultural production, forest and environmental income, income from other livelihoods strategies including business income, wage labor, salaries, remittances, gifts etc., expenditures, access to forest resources, and shocks experienced by the household. Our household survey was designed to mirror prior waves of the MFLS, but also to include new modules focused on household energy and cooking. The survey was administered by a team of skilled enumerators that underwent 10 days of classroom training followed by a 3 day pre-test outside of the study districts.

For each household selected we also conducted a separate interview with the primary cook. Primary cooks were defined as those who cooked more than 50% of the meals in the household during the past 30 days. The primary cook survey includes modules on cook demographics, frequency and seasonality of cooking practices, household food consumption, kitchen design and ventilation, fuel use, cooking technology choices, other environmental exposures, awareness about the health, environmental and air pollution implications of cooking choices (i.e., have households been informed by forest officials, NGOs, schools etc. that reliance on fuelwood and charcoal has negative consequences), perceptions of attributes of traditional stoves vs. improved stoves, and indicators of health status of the cook and children under five. In almost all cases we interviewed household decision makers before we interviewed cooks, and the surveys were general administered one after the other. After the cook survey we asked the cook whether they would like the stove or the sugar. Sometimes the cook made the decision independently, but often there was consultation with the household head. This study was reviewed and approved prior to its start by the Institutional Review Board (IRB) at the University of North Carolina at Chapel Hill; participants provided written consent.

2.2 Analysis

We model the choice of stove or sugar as a binomial discrete choice model (Ben-Akira, 1993). In this model, household i from a sample of N households choses from a feasible set P=1, 2 where 1 denotes ICS and 2 denotes dry goods (sugar and salt), respectively. U_1 and U_2 represent the utility derived from choosing ICS and dry good, respectively. The choice decisions of the household can be expressed as

$$P_i=\begin{cases} 1 & \text{if } U_1>U_2 \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

Equation 1 suggests that the household will only choose ICS, based on the respondent's assessment of the idiosyncratic benefits of choosing a stove (medium to long-term benefit) against dry goods sugar and salt (meeting immediate needs). The choice decisions may be influenced by demand-side factors (D_i), supply-side factors (S_i), knowledge of the cook regarding benefits and risks of ICS adoption (K_i), and characteristics of the primary cook and cooking environment (C_i). Each of our models includes a set of household-level control variables (H_i). Households are nested within villages; we include a number of meso-level factors hypothesized to influence adoption decisions (V^j). As our data come from two geographically distinct study areas we estimate a set of models of each study area and then pool the data. Formally, our model is specified as follows:

$$\mathrm{Chose\,Stove_i}=\mathrm{f(D_i,\ S_i,\ K_i\,C_i,\ H_i,\ V_i)} \quad (2)$$

where:

> Chose Stove_i is whether the household i selected the ICS or sugar, where 0 is 'No' and 1 is 'Yes'.

To leverage the nested structure of our data we estimate a series of multi-level models where households are nested within villages. This modeling structure allows us to account for highly variable numbers of observations at the village through partial pooling (Gelman, 2006). In contrast to a standard cross-sectional regression approach, where varying intercepts or coefficients are introduced through dummy variables and interaction terms, multilevel models allow us to simultaneously and efficiently estimate group-level effects and predictors (Gelman, 2006), and to account for the fact that error terms between household within a village may be more highly correlated than errors in households between villages. Our results are presented as odds ratios. Summary statistics for the variables used in the regression models are found in Table 2. Asterisks are used in the tables to indicate p-values. Standard errors are clustered at the level of 44 villages. Prior to implementation, diagnostic tests were conducted to ensure regressions were free from variance inflation, non-linearity and non-normality. We supplement our quantitative analysis with qualitative data from an open ended question at the end of the survey about why the household chose the stove or sugar.

3. Results

Overall, 66.0% of households in our sample of 383 households chose the ICS (78.4% in Kasungu District; 53.4% in Machinga District) (Table 2). Willingness to adopt the stove was higher than expected given that both study areas have a relatively abundant supply of fuelwood. Our two study areas are statistically significantly different with respect to average annual fuelwood consumption (kg) and average number of adult equivalents in the household (indicators of demand for ICS). Controlling for adult equivalents, fuelwood consumption is statistically significantly higher in Kasungu District (525 vs. 401 kg/adult equivalent/year). We observe few differences on the supply side. The only variable with a weakly significant difference is area of forest land owned (ha); households in Kasungu own larger plots of forest than those in Machinga District.

We do not observe large differences between study areas with respect to knowledge about health, environment and climate impacts of household air pollution from burning biomass. We do observe differences in the demographic characteristics of our sample between the two study areas. In Kasungu District the average age and education level of cooks and household heads is higher and statistically significantly different than for households in Machinga District. We also observe a difference in the number of households cooking inside; 88% of households in Kasungu cook indoors, whereas 81% of households in Machinga cook inside. We note that there is a substantive difference in kitchen design in the two study areas; kitchens in Kasungu District are typically much better ventilated (i.e. they typically are built with half walls leaving the upper half of the building open). The Kasungu study area is more ethnically homogeneous than Machinga (85% of households are from the dominant ethnic group as compared with 60% in Machinga), and households in Kasungu are on average weakly statistically significantly wealthier than those in Machinga. We also find evidence of stronger peer effects in Kasungu (79% of households selected the stove or sugar/salt following what their neighbors within their village chose as compared with 53% in Machinga), and we observe a statistically significantly higher number of villages with active Village Natural Resources Management Committees (VNRMC) in Machinga than in Kasungu District.[3]

Our econometric analysis of the determinants of stove adoption suggest that supply side factors influence adoption but through various pathways (Table 3). Our most robust results suggest that households that rely on crop residues (primarily maize cobs) as a source of fuel were more likely to adopt the ICS in Machinga District. Though not statistically significant, reliance on crop residues also increased the odds of ICS adoption in Kasungu and for the pooled sample. In Kasungu District, and for the pooled sample, households where people other than the cook (e.g., children) spend more time collecting fuel, have lower odds of choosing the ICS. In Machinga District, where land holdings are smaller, we find that

[3]Village Natural Resource Management Committees are community-level institutions responsible for developing forest management plans, which include the development of local management rules, harvesting fees, and sanctions on customary lands. They work in close collaboration with District Forest Officers (IIED, 2008).

households with larger forest plots are more likely to adopt the ICS (OR 2.331). We did not find any evidence that demand side factors (current fuelwood usage rates and household size) influence stove adoption.

Knowledge of health and climate impacts of household air pollution had no discernable effect on the choice of the ICS over sugar. We found that in Kasungu District and for the pooled sample, knowledge of the environmental impacts of biomass reliance on deforestation and forest degradation increased the odds of ICS adoption. We note that this result is significant at the 10% level and is not robust across the two field sites.

Demographics and experience of the primary cook in the household affect willingness to adopt ICS. Our strongest predictors are the number of hours per week the primary cook spends collecting fuelwood (OR 1.151 for pooled sample), and whether or not the household has had an experience with a non-traditional stove (OR 0.457). In Machinga District and in the pooled sample, a 1 hour increase in fuel collection on a weekly basis led to a 15–17% increase in the odds of ICS adoption. We detect a robust effect of past or current experience with a non-traditional cooking technology, which reduced the odds of stove adoption. We find weak evidence that number of years of experience as a cook (Machinga District), and having a female headed household (Kasungu District and pooled sample) increased the odds of stove adoption but these results were not robust across sites. We find that higher values of household assets increased the odds of willingness to adopt an ICS. At the village-level and for our model overall, a strong determinant of stove adoption was peer effects at the village-level. Having others in the village chose the stove increased the odds of any single household selected the stove by approximately 6%. In addition to collecting quantitative data for variables we hypothesized as determinants of stove adoption we also directly asked households why they selected the stove over the sugar and salt. The most common responses given were: that the stove saves fuelwood (22%); the stove is an asset/durable good (20%); stoves make cooking easier and cleaner (20%); stoves are portable (14%); and the cook wanted to have the experience of cooking on an improved stove (10%).

We visited a random sample of 121 households (roughly 50% of the households that chose stoves) in late March 2014 to assess rates of adoption and utilization approximately 6 months after the stoves were originally distributed. We found that 80% of households were actively using the stoves they received in October/November 2013 (81% and 80% in Kasungu and Machinga respectively). We find that households reported using stoves for 63% of all cooking events. When asked about stove use within the past 24 hours, 54% of household reported using the stove three times, and 25% reported using the stove 2 times. Exclusive use of the ICS during the past 7 days was rare. Overall user experience with the chitetezo mbaula was favorable. When asked about how the chitetezo mbaula affected the cooking experience relative to the baseline technology 96.9% indicated a reduction in smoke in the kitchen, 95.9% incited a reduction in incidence of burns/accidents, 87.8% indicated a reduction in cooking time, and 98.9% of household experienced a reduction in time spent collecting wood.

Given the small sample size in the follow-up study we simply compare mean values for households that reported adoption and sustained use (whether exclusive or idiosyncratic) with those that indicated they were no longer using the stove, or had never used the stove. We find that households with a relatively high level of knowledge regarding the health impacts of household air pollution were less likely to use the stove (52.4% compared with 28.6%), and that households with higher per capita incomes were also less likely to use the stove (average income of $335 USD for non-users vs. $213 USD for users). Both of these results are statistically significant at the 5% level. Respondents to the follow-up survey indicated a generally high level of satisfaction with the stoves. When asked where they could purchase a second stove or obtain a replacement, very few respondents were knowledgeable about places to source stoves suggesting supply-side factors for ICS are a major constraint to wide-scale adoption of stoves and should be considered as interventions are designed and brought to scale.

4. Discussion

Our aim in conducting this experiment was to push our understanding of the determinants of improved cookstove adoption beyond the often cited demographic and socioeconomic characteristics of households. We consider factors influencing fuel demand (fuel use and number of adult equivalents in the household) and fuel supply (forest ownership, types of fuel available for use, and time to nearest forest and labor availability for collecting fuel). We expected variables reflecting high demand for fuel and constraints on labor and or fuel supply to be positively correlated with willingness to adopt ICS. We find limited evidence that demand side factors influence ICS adoption. This suggests that households do not equate fuel savings with ICS use, or that fuel savings are not a motivating factor in ICS adoption.

In our study fuel supply influences ICS adoption. Household-level forest ownership was associated with ICS adoption suggesting an interest in conserving own forest resources. Households using high shares of crop residues as fuel were more likely to adopt ICS. Reliance on crop residues may signal fuelwood scarcity or lack of access; heavy reliance on crop residues was associated with the lowest income households. We also find that households with a large labor force (i.e., other than primary cook) for fuel collection were less likely to adopt ICS. Taken together, our findings confirm the importance of considering supply-side factors, which are often omitted from ICS adoption and fuel use studies, (c.f., Jagger and Shively 2013) in influencing household decisions.

Our findings on knowledge of the health and environmental implications of fuel choice and cooking practices are mixed. We find a positive association between knowledge about the environmental implications (e.g. forest degradation, watershed management etc.) of solid fuels and traditional cooking technologies and stove adoption for Kasungu and for the pooled sample. This finding is not robust in Machinga District, even though a large share of households had knowledge of environmental impacts, and deforestation and forest degradation are more pressing issues in the Machinga field site. Our results regarding knowledge about the health effects of exposure to household air pollution are unexpected, but consistent with findings from a study in Bangladesh indicating that women do not perceive household air pollution as a high-priority health issue (Mobarak et al., 2012). We hypothesized a positive relationship with stove adoption, but find that among households that selected the stove, those with knowledge of the health impacts of HAP were far less likely to exhibit sustained use of the stove. A possible explanation for this result is that households were expecting a complete reduction in smoke with the ICS, which would be uncommon with most biomass burning ICS.

We did not find strong evidence that the demographic characteristics of cooks are driving adoption decisions. Rather what increases the odds of adoption is a large number of hours spent by the cook collecting fuel, suggesting that cooks seek to limit the amount of time required to collect fuel. Marketing stoves as time saving technologies for cooks is a potential avenue for increasing ICS adoption. This finding taken in tandem with result on non-cook labor allocated to fuel collection suggests that household decision makers prioritize the value of their time over the value of others in the household who collect fuel, including children. Importantly we find that experience with a non-traditional cookstove of any type (current or sometime in the past) decreases the odds of stove adoption. This may be because households already have an improved stove and feel that they do not need another, or may be because they have had a negative experience with a non-traditional stove. This relationship was observed in Kasungu where a number of stove programs with mixed results have taken place in the recent past.

We considered three meso-level variables that we expected would influence ICS adoption: peer effects or how many other households in the village selected the stove over sugar; whether an NGO promoting ICS had visited the village within the past 12 months; and whether the village as has an active Village Natural Resources Management Committee (VNRMC). The most important variable is peer effects which statistically significantly increases the odds of stove adoption in both study areas and for the pooled sample. This suggests that peer effects or focusing on leaders and other respected community members may play a key role in ICS adoption in Malawi. Our findings are consistent with evidence from an ICS adoption study in Bangladesh that social networks and influence of opinion leaders play a significant positive role in shaping households' stove purchase decision (Miller and Mobarak, 2011).

Our findings on adoption and use of ICS are encouraging but should be viewed in the context of known survey bias with respect to reporting adoption and utilization (Ruiz-Mercado et al., 2011; Thomas et al., 2013). We flag that given the nature of our survey (i.e., forests and livelihoods, household energy, health), that respondents were probably more likely to select the stove, than if we had conducted a survey about livestock rearing or some other topic unrelated to household energy issues. Further, survey respondents may over-represent usage as much as a factor of two. Accounting for potential over-reporting bias in our results would conservatively place adoption and sustained (though non-exclusive) ICS utilization at approximately 40%. To place our results in context, adoption rates for ICS interventions widely vary from 2% in Bangladesh (Mobarak et al., 2012), to 40% in rural Mexico (Ruiz-Mercado et al., 2011), to 60% in Kenya (; (Silk et al., 2012). A small RCT intervention study in Senegal (N=253) with free cookstoves had almost a 100% adoption rate (Bensch and Peters, 2013). Our findings are encouraging relative to other improved cookstove adoption studies.

5. Conclusion and Policy Implications

It is estimated that the rural market penetration of cookstove programs in Malawi is only about 50,000 (GVEP International, 2013). Given the limited reach of the market it should not be surprising that many households are not aware of ICS and their potential benefits. Several bilateral donors (e.g., Ireland, the United States, and Germany) have pledged support towards achieving the goal of two million ICS by 2020, and the Malawi National Cookstove Steering Committee has been formed to develop a strategy for scaling-up the adoption of improved cooking stoves. With clear endorsement from national policy makers and backing from the international community several ICS interventions are planned in Malawi and in the region in the coming years.

The wide-scale adoption of improved cooking technologies is a formidable objective for most countries in sub-Saharan Africa. A myriad of challenges face the policy makers, donor objectives and implementers who are working towards large-scale ICS adoption in very poor countries like Malawi. The willingness of 66% of households in our sample to adopt ICS is an encouraging result. Given that our study takes place in an area of relative fuel abundance, we expect that in more fuel constrained areas, rates of adoption and utilization would be higher.

Our study has several limitations. First, we acknowledge that our analysis primarily focuses on willingness to adopt and provides only limited information about the sustainable use of ICS. If health and climate impacts are to be successfully mitigated through the adoption of improved cooking technologies, information on what determines sustained utilization is necessary. Studies that extend beyond surveys to incorporate stove use monitors are needed. Second, our sample is drawn from a panel survey of approximately 400 households with the first wave taking place in 2002. Roughly 50% of the original sample has been retained, meaning that our sample has a bias towards older and more established households. Finally, we acknowledge that the recent literature on ICS adoption literature focuses on the supply of cookstoves including aspects of pricing and marketing of cookstoves. Our analysis considers a case where people are asked to choose between two goods of equal value. In that way the stoves are not free, but valued at the cost of forgone sugar/salt consumption by the household. In designing our experiment, we sidestep issues of cookstove production, distribution, quality, pricing and marketing which are central to achieving successful scale-up.

Policy makers should be encouraged by the willingness of rural households to adopt ICS. Rates of uptake were much higher than expected, particularly given the abundance of fuelwood in the study areas. Despite this relative abundance, supply side factors, labor constraints on fuelwood collection (e.g. when the cook is heavily vested in collecting fuelwood), and information about the environmental implications of dependence on biomass as a cooking fuel motivate willingness to adopt. If environmental messages resonate with rural smallholders, more effort should be placed on emphasizing the environmental and health gains to potential ICS users. We flag the negative impacts of past experience with non-traditional and often inappropriately promoted as “improved” cooking technologies as an issue for policy makers to address. Our findings reflect a ubiquity of negative experiences with ICS, or a lack of interest in trying multiple technologies for those households that presently own an ICS. For a successful scale-up, this barrier will need to be overcome. We also highlight the very important role of peer effects in our findings. In the Malawian context, getting support from local leaders, and ensuring that the majority if not all members of a village have access to ICS may be the most effective way to scale-up quickly. Finally, we encourage policy makers to experiment with multiple models of ICS distribution and marketing. Our analysis suggests that the majority of households are willing to trade-off short-term consumption to acquire a relatively low value asset that has short, medium and long-term private and social benefits. We put forward the idea of subsidizing appropriate, low cost, and locally sourced ICS to overcome barriers to adoption. Under the right conditions, the provision of subsidies on ICS along with civic education and greater involvement of local people in the design, production, and promotion of ICS may foster wider acceptance and uptake by rural households.

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Highlights

- There is demand for locally produced improved cookstoves in rural Malawi
- Environmental awareness, labor availability, and peer effects influence adoption
- Sustained and exclusive use of improved cookstoves requires training and follow-up

1a: Chitetezo mbaula 1b: Cooking with the chitetezo mbaula

Figure 1.
Chitezo mbaula (‘protecting stove’) produced in Malawi (Photo credit: Maria Thundu)

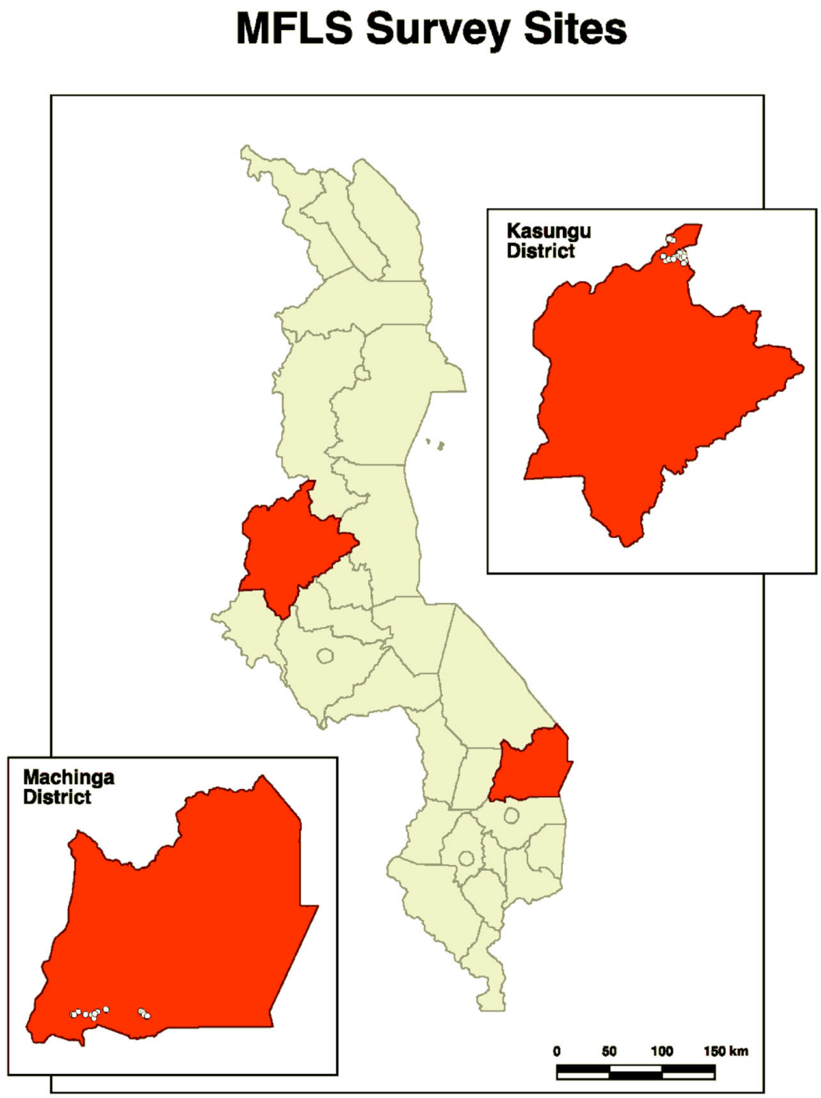

Figure 2.
Map of study area

Table 1

Characteristics of study villages, mean[a]

	Kasungu	Machinga	Malawi
Percent tree cover, 2010	13.5 (4.4)	26.6 (2.1)	18.6 (7.4)
Precipitation in 2010, mm/year	936 (9)	1143.5 (13.1)	1017 (103)
Distance to nearest city, km	118.5 (1.5)	72.0 (1.1)	100.3 (23.2)
Distance to nearest road, km	1.2 (0.8)	0.64 (0.7)	1.0 (0.7)
Population density, 2010 (persons/square km)	93.4 (29.3)	132.6 (111.4)	108.8 (74.1)
Distance to nearest protected area (kms)	1.5 (1.2)	2.6 (1.1)	1.9 (1.3)
Elevation (m.a.s.l.)	1274 (34)	761 (31.2)	1073 (257)
Average land holding (hectares)	1.5 (1.07)	0.76 (0.71)	1.20 (0.98)
Number of villages in sample	26	18	44

[a]Standard deviation reported in parentheses.

Table 2

Descriptive statistics for study sites[a,b]

	Mean(St.dev)				
	Kasungu	Machinga	Pooled	Min	Max
Chose stove (percent)	78.4 (41.2)	53.4 (50.0)	66.0*** (47.5)	0	100
Demand side factors					
Fuelwood consumption (kilograms)	2,466 (1,864)	1,370 (1,284)	1,914*** (1,688)	0	20800
Adult equivalents (number)	5.2 (2.1)	3.9 (1.6)	4.5*** (2.0)	1	14
Supply side factors					
Forest land owned by household (hectares)	0.36 (1.24)	0.11 (0.41)	0.24* (0.93)	0	12
Share of fuel that is low quality fuelwood (percent)	34.5 (35.4)	63.8 (32.5)	49.3 (36.9)	0	100
Share of fuel that is crop residue (percent)	1.0 (4.3)	9.6 (19.6)	5.3 (14.9)	0	100
Distance from household to nearest forest edge (minutes walking)	37.2 (48.5)	33.0 (29.9)	35.1 (40.2)	1	360
Time household members (not cook) spend collecting fuel (hours/week)	6.6 (9.5)	5.8 (8.1)	6.2 (8.8)	0	90
Knowledge of impacts of biomass reliance					
Aware of health impacts (percent)	26.8 (44.4)	32.6 (47.0)	29.8 (45.8)	0	100
Aware of environmental impacts on forest (percent)	54.7 (49.9)	76.2 (42.7)	65.5 (47.6)	0	100
Aware of climate impacts of air pollution (percent)	18.4 (38.9)	34.7 (47.7)	26.6 (44.3)	0	100
Demographics and experience of primary cook					
Experience as primary cook in this household (years)	21.1 (12.4)	18.4 (14.4)	19.7** (13.5)	0	70
Time primary cook spends collecting fuel (hours/week)	3.6 (2.6)	3.4 (3.5)	3.5 (3.1)	0	15
Past or current experience with non-traditional stove (0/1)	0.08 (0.27)	0.21 (0.41)	0.15 (0.35)	0	1
Cooks indoors (0/1)	0.88 (0.32)	0.81 (0.39)	0.85** (0.36)	0	1
Age cook (years)	42.6 (14.4)	41.0 (17.1)	41.8 (15.8)	13	96
Cook has some primary or secondary education (0/1)	0.89 (0.31)	0.73 (0.44)	0.81*** (0.39)	0	1
Household-level controls					
Age of household head (years)	54.1 (13.6)	48.1 (17.8)	51.1*** (16.1)	19	99
Female headed household (0/1)	0.16 (0.37)	0.33 (0.47)	0.25 (0.43)	0	1
Head has some primary or secondary education (0/1)	0.92 (0.26)	0.82 (0.38)	0.87** (0.33)	0	1

	Mean(St.dev)			Min	Max
	Kasungu	Machinga	Pooled		
Head is from dominant ethnic group (0/1)	0.85 (0.36)	0.60 (0.49)	0.72*** (0.45)	0	1
Value of assets (Malawian Kwacha)[c]	40,405 (62,809)	31,622 (45,238)	35,979* (54,770)	500	460,200
Total income (Malawian Kwacha)[c]	372,148 (437,125)	396,480 (761,219)	384,409 (621,234)	3,750	8,095,350
Village-level variables					
Share of other study households that chose stove in village (percent)	78.8 (17.2)	53.1 (20.4)	65.9*** (22.8)	0	100
NGO promoting ICS has visited village in past 12 months (0/1)	0.44 (0.50)	0.45 (0.50)	0.45 (0.50)	0	1
Active Village Natural Resources Management Committee (0/1)	0.85 (0.36)	0.63 (0.48)	0.74*** (0.44)	0	1
Number of households	190	193	383		
Number of villages	26	18	44		

[a]Standard deviations reported in parentheses.

[b]*,**,*** Statistically significant difference of means at the 10, 5 and 1 % levels respectively.

[c]In October/November 2013 1USD=360 Malawian Kwacha

Table 3

Odds of choosing stove over sugar, multi-level mixed effect logit models[a,b]

	Kasungu	Machinga	Pooled
Demand side factors			
Fuelwood consumption (100 kgs)	0.981 (0.184)	0.889 (0.082)	0.908 (0.069)
Adult equivalents (number)	0.944 (0.131)	0.900 (0.124)	0.943 (0.078)
Supply side factors			
Forest land owned by household (hectares)	1.201 (0.440)	2.331* (1.137)	1.357 (0.316)
Share of fuel that is low quality fuelwood (percent)	0.986* (0.008)	1.003 (0.006)	0.997 (0.004)
Share of fuel that is crop residue (percent)	1.057 (0.060)	1.022** (0.011)	1.013 (0.010)
Distance from household to nearest forest edge (minutes walking)	0.999 (0.005)	1.006 (0.006)	1.004 (0.004)
Time household members (not cook) spend collecting fuel (hours/week)	0.933** (0.026)	1.014 (0.028)	0.972* (0.016)
Knowledge of impacts of biomass reliance			
Aware of health impacts (0/1)	1.467 (0.936)	1.620 (0.677)	1.352 (0.432)
Aware of environmental impacts on forest (0/1)	2.709* (1.635)	0.739 (0.392)	1.752* (0.558)
Aware of climate impacts of air pollution (0/1)	0.574 (0.370)	0.933 (0.384)	0.679 (0.214)
Demographics and experience of primary cook			
Experience as primary cook in this household (years)	0.987 (0.037)	1.042* (0.024)	1.023 (0.017)
Time primary cook spends collecting fuel (hours/week)	1.139 (0.124)	1.173** (0.082)	1.151*** (0.060)
Past or current experience with non-traditional stove (0/1)	0.117** (0.100)	0.771 (0.385)	0.457** (0.184)
Cooks indoors (0/1)	0.598 (0.565)	1.818 (0.917)	1.179 (0.451)
Age cook (years)	1.006 (0.038)	0.985 (0.022)	0.987 (0.016)
Cook has some primary or secondary education (0/1)	0.301 (0.375)	1.101 (0.576)	0.732 (0.320)
Household-level controls			
Age of household head (years)	0.984 (0.023)	1.001 (0.016)	1.004 (0.012)
Female headed household (0/1)	3.800* (2.948)	1.644 (0.812)	2.014* (0.745)
Head has some primary or secondary education (0/1)	2.037 (2.055)	1551 (1.028)	1.517 (0.773)
Head is from dominant ethnic group (0/1)	1.323 (0.864)	0.783 (0.324)	1.076 (0.341)
Value of assets (ln), Malawi Kwacha	1.728** (0.415)	1.175 (0.212)	1.252* (0.156)
Total income (ln), Malawi Kwacha	0.850 (0.303)	1.058 (0.013)	1.038 (0.175)
Village-level variables			
Share of other study households that chose stove in village (percent)	1.094*** (0.021)	1.058*** (0.013)	1.062*** (0.010)
NGO promoting ICS has visited village in past 12 months (0/1)	1.266 (0.696)	1.088 (0.436)	1.135 (0.332)
Village has active Village Natural Resources Management Committee (0/1)	1.339 (0.916)	1.232 (0.498)	1.062 (0.334)
Machinga (c.f. Kasungu)	-	-	1.119 (0.494)
Constant	0.001 (0.006)	0.001** (0.003)	0.002** (0.005)
N (households)	190	193	383
N (villages)	26	18	44
Log likelihood	−61.624	−98.311	−181.783

	Kasungu	Machinga	Pooled
AIC	177.249	250.621	419.565
BIC	264.919	383.714	530.110

[a]Standard errors reported in parentheses – clustered at the village-level.

[b]*,**,*** Statistically significant at the 10, 5 and 1 % levels respectively.